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Pulling Students In: Creating Concrete Experiences through a Simple Pulley Device

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Creating Concrete Experiences Through a Simple Pulley Device

Photo by Kriss Szkurlatowski

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ABSTRACT: Physics is often taught with an emphasis on mathematical relationships. Many teachers use equations to teach, assuming that the content will fall into place. In reality, all students benefit from concrete representations and familiar objects and properties before learning abstractions (Karplus, 1977). Since mathematics is inherently abstract it must be reserved until after students have a firm conceptual understanding. This article provides a concrete activity that encourages students to explore pulleys. *This activity promotes National Science Education Content Standards A, B, E, and F. It also addresses Iowa Teaching Standards 1, 2, 3, 4, and 5.*

Unlike the common experiences of pushing and pulling, most students have not physically operated a pulley or experienced first-hand their usefulness. Therefore, students must first explore the properties of pulleys before they learn how pulleys relate to other ideas in physics. Likewise, only after students have rich experiences with pulleys is introducing mathematics appropriate. The following activity is how we have attempted to represent pulleys more concretely so that students can investigate the properties of pulleys rather than simply memorize formulas.

We consider the activity described below to be the initial exploration of pulleys. This activity will provide students with rich concrete experiences to which more abstract ideas can be linked. To what extent you continue beyond this activity will depend upon grade level, students' mathematical abilities, and your curriculum.

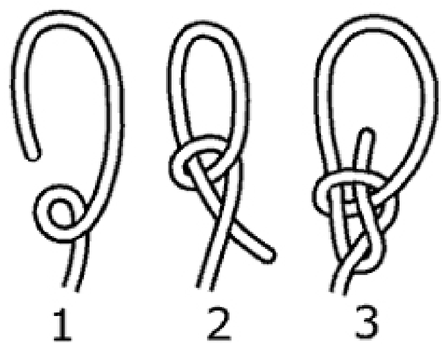
Exploring Pulleys

Before the first day of this activity gather the following equipment:

- Two thick metal rods for every group of three students. The rods used for ring stands are ideal, although thick wood broomsticks will also work.
- One strong rope, approximately five meters long, for every group of three students.. A used climbing rope would be ideal.
- Meter stick

Tie one end of each rope very firmly to one of the rods. Standard square knots have a tendency of coming loose; a bowline knot (Figure 1) is far sturdier and easier to untie at the end of the activity. After these knots are tied confirm they are tight and not easily removed. The other end of the rope should remain untied.

FIGURE 1
Steps for completing a bowline knot.



http://www.leverknot.com/basic_use/basic_use.htm

To start the activity, we assess students' understanding of prior content while preparing students for the exploratory activity by asking probing questions such as

- "What are some ways people can move heavy objects?"
- "What are some examples of tools that do not use gas or electricity?"
- "Why might it be useful to have tools that do not require gas or electricity?"

These questions provide a sense of what students already know and provide some context for the activity. We typically ask these questions to the whole class. Because students are likely unsure of their knowledge, we provide a welcoming expression on our face and do not judge student responses as right or wrong. We simply want to know what students think regarding these topics. We use plenty of wait time and look around at students expectantly to encourage more responses. We want to know students ideas in order to understand student thinking and use their ideas to lead the discussion.

If students mentioned pulleys in the earlier discussion, we hold up two rods and a rope and ask how a pulley could be made using the rods and rope. If pulleys were not mentioned, we ask students how the rods and rope might be used to pull something that would be too heavy to pull with just a rope. If students struggle with a response, we have them discuss with a partner. This strategy encourages students to mentally engage with the challenge in a smaller, less intimidating setting. We want student to think critically about how they might more easily move a heavy object rather than simply wait for the teacher's direction. These small group discussions encourage students to bounce ideas off one another and evaluate each other's thinking. While students are discussing their ideas, we do not simply stay at the front of the room. We use this opportunity to walk around the classroom, listen in on student conversations and ask questions to the groups with the intent of carefully guiding them through the activity.

After students have discussed is small groups, we come back together as a class and share ideas. Students often suggest putting the heavy object on the rods to act as rollers and reduce friction or using the rods as levers to move the heavy object. Rarely do students come up with a pulley system from these small group discussions. Yet, having these discussions mentally prepares them for when we introduce the idea of pulleys.

Pulley Demonstration

After discussing groups' ideas as a whole class, we ask two "strong" students to come to the front of the room for a demonstration. Once the students are there, we note the greater strength of the two students compared to the one teacher. Then, we claim to be able to overcome their combined power with the help of the rods and rope. Specifically, we might say,

- "I'm going to attempt to pull these two students closer to each other while they try to pull apart as hard as they can. How do you think I can do this with the rope and two rods?"

We discuss the merits of students' ideas and explanations by either trying out the ideas or asking follow-up questions to explore the logic of the ideas. For example, if students suggest wrapping the rope around the students, we might ask,

- "If we wrap the rope around the students, they might get rope burns. Why do you think wrapping the rope would help?"
- "How could we wrap the rope without harming the students?"

If students do not suggest the configuration shown in Figure 2, we demonstrate it by handing each student volunteer a rod (remember, one has the rope tied to it), and wrap the rope around the rods as shown. Asking the students to resist being pulled together, we pull on the rope to slowly pull the students together. Then we ask the class,

- "How was I able to overpower these two students?"

Students typically note that by wrapping the rope several times, we are increasing our power. When students say something like this, we ask for clarification by asking,

- “I am still me, so my strength wasn't different. What was different?”

Students quickly note that the effectiveness of our force was increased. We ask students how this might be the case and look expectantly around the room for ideas. After students put forth ideas, we ask for clarification or even continue to look around the room to encourage other students to comment. While students already have interesting ideas, they are now ready to make more detailed observations of the pulley system. This brainstorming session and discussion provide students with an introduction to how the system works. From here students can test their ideas to determine how this system actually works.

FIGURE 2
Pulley set-up for the initial class demonstration.

Pulley Observation

Student groups already have the rods and ropes from their previous brainstorming session. Given the demonstration we just conducted, we encourage the students to explore the pulley systems. We put the following questions on the board to guide their exploration and thinking:

- “How can you modify your pulley to reduce the amount of input force required?”
- “Why do you think such modifications reduce the amount of input force required?”
- “What do you notice about how the rope travels throughout the pulley system?”

What trade offs come with reducing the required input force? As students work in their groups of three, we walk around the room. As we move around, we listen to students conversations, redirect off-task behavior and pose questions to students, which helps to scaffold their thinking concerning the above guiding questions. For example, if groups struggle with the first question we might ask,

- “What about the pulley system do you think made it possible for me to pull the two students together?”

Or, if more guidance is needed,

- “How do you think the number of times the rope is wrapped around the poles will affect the force needed?"
  - "How could you test this idea?”

Typically, students struggle with the question, “What trade offs come with reducing the required input force?” After some initial exploration, we draw students' attention to the length of rope and distance it must travel to obtain the same force (Colburn & Clough, 1997) by asking the class,

- “When the rope is wrapped once, how much rope does it take to move the stick holder a meter?”
- “How do you think this distance will compare when the rope is wrapped four times?”

After listening to a few students' predictions and eliciting some explanation, we have the students investigate these questions.

After students have explored the pulleys for 10-15 minutes we ask them to take a few minutes and individually write in their notebooks about the three questions on the board. While students write, we collect the ropes and rods, but keep at least one set out for further demonstration. We collect the ropes and rods to avoid distraction during the next discussion. As we walk around collecting the ropes, we scan the students' writing to gain insight into their thinking to this point. After a few minutes of writing time we lead a whole-class discussion related to the pulley investigation.

We ask the class each of the three questions. When students are explaining their thinking, we are sure to listen to what they say. After a student explains, we wait silently and look around the room expectantly to encourage other students to comment. If, after 3-4 seconds, students do not comment, we usually ask a follow-up question about explanation. This is an introductory activity, so we are genuinely seeking to understand students thinking so we can plan for later lessons. For example, we are not concerned that students come to understand the exact quantitative relationship between applied force by the puller and the distance traveled, but want students to have some indication that the pulley can move heavy objects, though the object will not travel as far.

Finally, we do not simply answer the three questions for the students. Initial exploratory labs give students a chance to develop their own understanding of science through creativity and curiosity and it would be inappropriate for us to replace this natural interest with lecture statements. That said, if we simply expected students to discover ideas from the exploration, most students would not come to understand the concepts we are after. If you decide to introduce more formalized concepts such as “work” (formulas, definitions, etc), this activity will provide students with background experiences to which you can connect the formal understandings (Pressley, Wood, Woloshyn, Martin, King, Menke, 1992).

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